

PATENT APPLICATION

**METHOD AND SYSTEM FOR IMPLEMENTING A SYSTEM
ACQUISITION FUNCTION FOR USE WITH A COMMUNICATION
DEVICE**

Inventor(s): Ghobad Heidari, a citizen of United States, residing at
13886 Camino Del Suelo,
San Diego, CA

Kuor-Hsin Chang, a citizen of Taiwan, residing at
1051 Rembrandt Drive,
Sunnyvale, CA

Assignee: QuickSilver Technology, Inc.
6640 Via Del Oro
Suite 120
San Jose, CA 95119

Entity: Small

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CROSS-REFERENCES TO RELATED APPLICATION(S)

5 [01] The present application is a continuation-in-part application of U.S.
patent application serial no. 09/815,122 entitled "ADAPTIVE INTEGRATED CIRCUITRY
WITH HETEROGENEOUS AND RECONFIGURABLE MATRICES OF DIVERSE AND
ADAPTIVE COMPUTATIONAL UNITS HAVING FIXED, APPLICATION SPECIFIC
COMPUTATIONAL ELEMENTS," filed on March 22, 2001, the disclosure of which is
10 hereby incorporated by reference in their entirety as if set forth in full herein for all purposes.

BACKGROUND OF THE INVENTION

15 [02] The present invention generally relates to a system acquisition
function. More specifically, the present invention relates to a method and system for
implementing a system acquisition function for use with a communication device.

20 [03] In CDMA communication systems, each base station differentiates
amongst one another by using a unique PN code. A communication device, such as a
mobile phone, is equipped with a system acquisition function, typically embodied in a
searcher, to search for and locate the PN codes of the base stations within the vicinity of the
mobile phone. Upon power-on, one of the initial tasks of the mobile phone is to find the
strongest pilot signal from the nearby base stations as soon as possible. The task of finding
the strongest pilot signal is commonly known as system or pilot acquisition and is usually
performed by a searcher within the mobile phone.

25 [04] Under one conventional approach, the system acquisition function
within the mobile phone is implemented in the form of the searcher using a serial search
technique that only utilizes a set of complex correlators to search for the correlation peak
from one PN code offset to another. This approach consumes less power and requires less
hardware; however, the search for the correlation peak may take longer.

30 [05] Under another conventional approach, the searcher within the mobile
phone is implemented using a traditional parallel search technique that utilizes several sets of
fixed, dedicated correlators to compute the correlation peak in a concurrent manner. This
other approach may shorten the search time but it does so at cost of incurring more hardware

and power consumption. Furthermore, since the acquisition mode is typically less active than other modes, the exclusive use of fixed, dedicated correlators often results in a waste of hardware resources within the mobile phone.

[06] More specifically, system or pilot acquisition in a CDMA communication system is typically performed as follows. Each base station continually broadcasts its own unique PN code in a periodic manner. One PN code from one base station differs from another PN code from another base station by an offset. Before a PN code can be identified by the mobile phone, the mobile phone first searches for signals at a particular frequency. As a result, only signals from base stations transmitting at that particular frequency are received by the mobile phone.

[07] Next, the PN code of the base station which transmits the strongest pilot signal is identified and synchronized. The mobile phone receives signals from different base stations and these received signals are added up. Typically, the received signals are stored by the mobile phone before the correlation process begins. The mobile phone has a local PN sequence generator which is capable of generating sequences of PN codes. Initially, before the PN code of the base station which transmits the strongest pilot signal is identified, the PN sequence generator generates an initial PN code. This initial PN code is correlated with the received signals by a correlator residing in the mobile phone. Correlation is done to determine the power level of the received signals. The correlation results are examined to determine if the received signals representing the PN code of the transmitting base station fall within an acceptable time delay from the initial PN code to qualify as the strongest pilot signal. If the correlation results are below a predetermined threshold, i.e., the initial PN code generated by the local PN sequence generator does not qualify as the strongest pilot signal, then the local PN sequence generator shifts by one chip to generate another PN code and this other PN code is correlated with the received signals. The generation of PN codes and the correlation of these codes with the received signals continue until the strongest pilot signal is identified.

[08] When the strongest pilot signal is identified, the PN code generated by the PN sequence generator and used to identify the strongest pilot signal is synchronized with the PN code of the base station which transmits the strongest pilot signal. Once the synchronization of the PN code is achieved, the mobile phone is able to communicate with the base station.

[09] Furthermore, after pilot acquisition is completed, the mobile phone continues searching for nearby strong pilot signals and maintains a list to keep track of such

signals. This process is commonly called set maintenance. That is, in addition to the strongest pilot signal, the mobile phone also searches for and keeps track of a number of additional pilot signals (and their associated PN codes) with different levels of signal strength. For example, the mobile phone may maintain an active set which keeps track of additional multipaths associated with the pilot signal of the base station that the mobile phone is currently communicating with, a candidate set with pilot signals whose strengths exceed certain threshold, and a neighbor set that includes pilot signals from cells that are in the vicinity of the cells that the mobile phone is communicating with. Maintaining a number of additional pilot signals (and their associated PN codes) facilitates the handoff process. A handoff typically occurs when a mobile phone is roaming from one area to another. This happens when a pilot signal transmitted from another base station is stronger than the one that the mobile phone is currently communicating with. The candidate set may be used to more efficiently identify the new base station transmitting the strongest pilot signal. This is because the strongest pilot signal is more likely to be one of the signals included in the candidate set. Hence, the associated PN code can be retrieved more quickly and communication with the new base station likewise can be established in a shorter period of time.

[10] As can be seen above, the received signals need to be stored by the mobile phone so they can be subsequently used for correlation purposes. Furthermore, generation of the PN codes by the PN sequence generator is done in a sequential manner by shifting the current PN code.

[11] Hence, it would be desirable to provide a method and system to implement a searcher for use with a mobile phone to more efficiently identify the PN code of the base station which transmits the strongest pilot signal.

SUMMARY OF THE INVENTION

[12] A method and system for implementing a system acquisition function for use with a communication device is provided. According to one exemplary embodiment of the system, the system acquisition function is embodied in a searcher. The searcher is embedded in the communication device, such as, a mobile phone. The searcher includes one or more computational units which are used to perform a PN sequence generation function to generate PN sequences. Each PN sequence is comprised of a number of PN codes. The searcher further includes a number of computational units which are used to correlate received signal samples with the PN codes generated by the PN sequence generation

function. As each signal sample is received by the communication device, the received signal sample is correlated (complex multiplied) with a PN sequence in a parallel manner using the computational units. The sample correlation results are then respectively accumulated within each computational unit that conducts the corresponding sample correlation. As the next signal sample is received, this newly received signal sample is similarly correlated with the next PN sequence in a parallel manner. Likewise, the sample correlation results are also accumulated. The foregoing process is repeated until all the signal samples needed to complete a signal correlation are received and correlated with the PN sequences. The number of PN codes within a PN sequence used to correlate with each received signal sample is equivalent to a correlation length chosen such that the correlation results between each received signal sample and the locally generated PN sequence are sufficiently reliable to determine whether the strongest pilot is found.

[13] According to another aspect of the system, the computational units are implemented using adaptive hardware resources. The number of computational units which are used to implement the PN sequence generation function and the correlation function are adjustable depending on, for example, the amount of available adaptive hardware resources.

[14] Reference to the remaining portions of the specification, including the drawings and claims, will realize other features and advantages of the present invention. Further features and advantages of the present invention, as well as the structure and operation of various embodiments of the present invention, are described in detail below with respect to accompanying drawings, like reference numbers indicate identical or functionally similar elements.

BRIEF DESCRIPTION OF THE DRAWINGS

[15] Fig. 1 is a simplified diagram illustrating an exemplary embodiment of an M-node having four (4) computational units in accordance with the present invention;

[16] Fig. 2 is a simplified diagram illustrating an exemplary method for performing correlations in accordance with the present invention;

[17] Fig. 3 is a simplified diagram illustrating the exemplary method as shown in Fig. 2 for performing an additional round of correlations in accordance with the present invention;

[18] Fig. 4 is a simplified diagram illustrating a second exemplary method for performing correlations in accordance with the present invention; and

[19] Fig. 5 is a simplified diagram illustrating a third exemplary method for performing correlations in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[20] The present invention in the form of one or more exemplary embodiments will now be described. Fig. 1 is a simplified diagram illustrating an exemplary embodiment of the present invention. Referring to Fig. 1, there is shown a searcher 10 having a number of computational units 12a-m. The searcher 10 can be located in any type of communication device, such as a mobile phone. As will be further demonstrated below, each computational unit 12a-m correlates the received signal samples with a corresponding PN code. In an exemplary embodiment, these computational units 12a-m are implemented using reconfigurable hardware resources within an adaptive computing architecture. Details relating to the adaptive computing architecture and how reconfigurable hardware resources are used to implement functions on an on-demand basis are disclosed in U.S. patent application serial no. 09/815,122 entitled "ADAPTIVE INTEGRATED CIRCUITRY WITH HETEROGENEOUS AND RECONFIGURABLE MATRICES OF DIVERSE AND ADAPTIVE COMPUTATIONAL UNITS HAVING FIXED, APPLICATION SPECIFIC COMPUTATIONAL ELEMENTS," filed on March 22, 2001, the disclosure of which is hereby incorporated by reference in their entirety as if set forth in full herein for all purposes. It should be understood that while the present invention is described as being in the searcher 10, it will be appreciated by a person of ordinary skill in the art that the present invention can be implemented in other manners within a communication device. For example, some or all of the functionality of the present invention as described herein may be implemented outside of the searcher 10 in other parts of the communication device.

[21] In an exemplary embodiment, the computational units 12a-m are arranged in a sequential order and configured to calculate the correlations between the received signal samples and a number of PN sequences. The start of any two adjacent PN sequences are offset by one chip. More specifically, the computational units 12a-m correlate each received signal sample with their corresponding components of a PN sequence in a parallel manner.

[22] The PN sequences used by the computational units 12a-m are generated in a successive, offset order. The starting position of each successive PN sequence is only one chip off from the preceding PN sequence. The PN codes of each PN sequence can be provided to the computational units 12a-m in a number of ways. For example, the PN

codes can be generated by either a PN sequence generator implemented in the form of another computational unit (not shown) or a RISC processor. As will be described further below, each PN code is shifted into a corresponding computational unit 12a-m. Each computational unit 12a-m includes a local memory for storing its corresponding PN code.

[23] Fig. 2 illustrates an exemplary method for performing correlations in accordance with the present invention. Assume the time duration of a received signal sample is T_d , that is, one signal sample is received every T_d . Then, conversely, the frequency of the received signal sample is $1/T_d = f_d$.

[24] Referring to Fig. 2, there are m computational units 20a-m within the searcher 10. At time t_0 , signal sample R_0 is received by a receiver (not shown) located within the communication device. Signal sample R_0 is then correlated with the PN sequence, $P_0P_1 \dots P_{M-1}$. The PN sequence, $P_0P_1 \dots P_{M-1}$, is generated by a PN sequence generator (not shown) located within the communication device. Since there are M PN codes within the PN sequence, M computational units 20a-m are used to do the correlations in parallel. Hence, each computational unit 20a-m correlates the signal sample R_0 with one PN code. For example, computational unit 20a correlates R_0 with P_0 to generate correlation result R_0P_0 . The collective correlation results generated by the computational units 20a-m are as follows: $R_0P_0, R_0P_1, \dots, R_0P_{M-1}$. The correlations are performed and the correlation results are respectively accumulated into the computational units 20a-m before the next signal sample R_1 is received at time t_1 . The signal sample R_0 may then be discarded after the correlations are performed.

[25] At time t_1 , signal sample R_1 is received. Signal sample R_1 is then correlated with a second PN sequence, $P_1P_2 \dots P_M$. The PN sequence, $P_1P_2 \dots P_M$, is only a shift of the PN sequence used at time t_0 plus a newly generated PN code P_M . That is, the start of the new PN sequence is offset by one chip from the preceding PN sequence. Consequently, the new PN sequence can be supplied to or propagated through the computational units 20a-m as follows. Except for the last computational unit 20m, each computational unit 20a-l receives its corresponding PN code for the next correlation from its neighbor. The last computational unit 20m receives its corresponding PN code P_M from the PN sequence generator. In other words, except for the first computational unit 20a, each remaining computational unit 20b-m passes its current PN code to its neighbor in the same direction. As to the first computational unit 20a, its current PN code is discarded; and as to the last computational unit 20m, as mentioned above, the PN sequence generator provides the next PN code. For example, after the correlations are completed for the received signal

sample R_0 (which is some time before time t_1), computational unit 20a discards its current PN code P_0 and receives its next PN code (which will be P_1) from computational unit 20b; computational unit 20m passes its current PN code P_{M-1} to its neighboring computational unit 20l (not shown) and receives its next PN code P_M from the PN sequence generator; and the remaining computational units 20b-l pass their current PN codes respectively to their neighbors in one direction and receive their next PN codes respectively from their neighbors in the other direction.

[26] Again, since there are M PN codes within a PN sequence, M computational units 20a-m are used to do the correlations in parallel. This time around, the collective correlation results generated by the computational units 20a-m are as follows: $R_1P_1, R_1P_2, \dots, R_1P_M$. The correlations are performed and the results are accumulated with the correlation results that were done at time t_0 before the next signal sample R_2 is received at time t_2 . Hence, for example, before time t_2 , computational unit 20a contains correlation results R_0P_0 and R_1P_1 . The foregoing process is repeated until the last signal sample R_{n-1} is received at time t_{n-1} and then correlated with the PN sequence, $P_{n-1}P_n \dots P_{M+n-2}$ generating the following collective correlation results: $R_{n-1}P_{n-1}, R_{n-1}P_n, \dots, R_{n-1}P_{M+n-2}$.

[27] At the end of the time period, $t_{n-1} + T_d$, the correlation results for the received signal samples, $R_0R_1 \dots R_{n-1}$, with n different PN sequences that are offset by one chip between the start of any two adjacent PN sequences, are then obtained. For example, $R_0P_0 + R_1P_1 + \dots + R_{n-1}P_{n-1}$ represent the correlation results accumulated at computational unit 20a. Also, at the end of the time period, $t_{n-1} + T_d$, M different PN code offsets have been searched. If the number of PN codes that need to be searched is M or fewer, then the entire search process is completed at the end of the time period $t_{n-1} + T_d$.

[28] If the number of PN codes that need to be searched is more than M , then a second round of search or correlations (or additional rounds if necessary) may be performed. The length (time-wise) of a round of correlations is the time period $t_{n-1} + T_d$. For example, Fig. 3 illustrates this second round of correlations. Before the second round of correlations begins, the accumulated correlation results in each of the computational unit 20a-m are transferred and stored in other memory locations and then cleared. Referring to Fig. 3, in the second round of correlations, the received signal sample R_n is correlated by the computational units 20a-m with the PN sequence, $P_{n+M}P_{n+M+1} \dots P_{n+2M-1}$ at time t_n . The correlation results are then accumulated at each of the computational unit 20a-m.

[29] At time t_{n+1} , the signal sample R_{n+1} is correlated with the next PN sequence, $P_{n+M+1}P_{n+M+2} \dots P_{n+2M}$. Similarly, the start of this next PN sequence is offset from

the preceding PN sequence by one chip and a new PN code is added at the end. This process will continue until the second round of correlations is completed. For the second round of real-time correlations, another M PN offsets ($P_M, P_{M+1}, \dots, P_{2M+1}$) are searched. The correlation results are then stored and cleared from each computational unit 20a-m before the next round of correlations starts.

[30] According to the exemplary method shown in Fig. 2, all the received signal samples R_x are not stored first and then later used for correlation purposes. Instead, as each signal sample R_x is received, the signal sample R_x is correlated with M PN codes and then accumulated. The collective correlation results for all the received signal samples R_x are then examined to identify the PN sequence which corresponds to the strongest pilot signal. Hence, the collective correlation results for the received signal samples R_x can be derived much faster. In addition, since all the received signal samples R_x need not be stored before the correlation function is performed, the memory overhead and hardware requirements and costs correspondingly become less.

[31] As can be seen from Fig. 2, for each time period T_d , M computational units 20a-m are used to correlate a received signal sample R_x with a PN sequence which has M PN codes. For each time period T_d , each computational unit 20a-m performs one correlation. As a result, with M computational units 20a-m, M correlations are collectively performed. As will be further described below, the number of computational units 20a-m which are used to perform the correlations is scalable. That is, the number of computational units 20a-m may vary depending on the amount of hardware resources available and the clock rate that is used to drive each computational unit.

[32] Referring back to Fig. 2, for each time period T_d and a PN sequence with M PN codes, each computational unit performs one correlation thereby resulting in M correlations being performed. However, each computational unit is not necessarily restricted to performing one correlation during each time period T_d .

[33] Each computational unit may perform two or more correlations per time period T_d . While M correlations are to be performed per time period T_d , these M correlations may be collectively performed by a fewer number of computational units. For example, referring to Fig. 4, there are $M/2$ computational units. In this case, each of the $M/2$ computational units is driven to perform two (2) correlations within the time period T_d ; for instance, computational unit 30a performs two (2) correlations and generates correlation results R_0P_0 and R_0P_1 . In order to perform two (2) correlations with the time period T_d , each computational unit is driven at a higher clock rate to increase the speed of execution.

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[34] In another example, as shown in Fig. 5, there are M/4 computational units. In this case, each of the M/4 computational units is driven to perform four (4) correlations within the time period T_d ; for instance, computational unit 40a performs four (4) correlations and generates correlation results R_0P_0 , R_0P_1 , R_0P_2 and R_0P_3 . In order to perform four (4) correlations with the time period T_d , each computational unit is driven at an even higher clock rate to increase the speed of execution.

[35] Based on the disclosure provided herein, a person of ordinary skill in the art should be able to determine the appropriate number of computational units to be used to implement the PN sequence generation function and the correlation function in accordance with the present invention. The number of computational units which can be used depends on a number of factors, such as the availability of the configurable hardware resources, the incoming signal rate or, conversely, the signal period, and the available clock rates, etc. For instance, if only a limited number of computational units can be used, then the clock rate may need to be driven higher in order to perform the requisite number of correlations.

Conversely, if additional hardware resources are available, additional computational units driven at a lower clock rate may be implemented to perform the same number of correlations. For another instance, if the signal period is shortened, then additional computational units may be needed to perform the requisite number of correlations within the signal period.

[36] The present invention as described above can also be used to provide more efficient set maintenance. Signals from the base station which previously transmitted the strongest pilot signal can be searched and correlated more quickly to confirm that this base station continues to be the one transmitting the strongest pilot signal. Likewise, signals from the base stations which correspond to the candidate set and the neighbor set respectively can also be searched and correlated more quickly to update the status of the neighbor set and the neighbor set. A candidate set may be searched more frequently than a neighbor set. As a result, the set maintenance update cycle is reduced.

[37] Moreover, while the above disclosure provided above is described in connection with a searcher 10, it should be understood that the present invention is not restricted to use with a searcher and that the present invention is applicable to and can be used with any communication devices which are capable of performing a system acquisition function.

[38] It is understood that the present invention as described above is applicable to a CDMA communication system but that a person of ordinary skill in the art

should know of other ways and/or methods to apply the present invention to other types of communication systems.

[39] Furthermore, it is to be understood that the present invention as described above can be implemented in the form of control logic using software, hardware or a combination of both. Based on the disclosure provided herein, a person of ordinary skill in the art will know of other ways and/or methods to implement the present invention.

[40] It is further understood that the examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be suggested to persons skilled in the art and are to be included within the spirit and purview of this application and scope of the appended claims. All publications, patents, and patent applications cited herein are hereby incorporated by reference for all purposes in their entirety.